Interim Report

On the

Phase II Corrosion Control Study
(DRAFT)

June 13, 2000

TABLE OF CONTENTS

BACKGROUND

The focus of the Phase II Corrosion Control Study has been to supplement research previously conducted by the Water Treatment Planning and Analysis Unit, reported in a document entitled "Final Report on the Corrosion Control Study for the New York City Water Supply System" issued in March, 1993. In that report, the following drinking water treatment procedure for compliance with the Lead and Copper Rule was recommended: (ref. p. 14): *"... [following passivation] sufficient caustic soda addition to maintain a pH of between 7.0 and 7.5 in the City's distribution system... [and] a continuous maintenance dosage of 2.5 ppm as [36% reactive phosphate] product (0.90 ppm as orthophosphate) is to be applied ... "*

This treatment recommendation was implemented for the Catskill and Delaware Water Supplies at Hill View Reservoir in November 1992 and for the Croton Water Supply at Jerome Park Reservoir in April 1993. Several weeks after introduction, significant improvements in high risk residential "first draw water" lead levels were indicated by the results of the EPA-mandated monitoring program conducted by the Division of Drinking Water Quality Control (DWQC). However, compliance with the Federally mandated Lead and Copper Rule's 90th percentile lead action level of 15 ppb had occurred only once, in July 1994, during the eight semi-annual distribution system regulatory monitoring periods which transpired between December 1993 and July 1996.

While it remains plausible that the failure to have continually met the EPA Rule occurred for several reasons, including the sub-optimal performance of the Interim Treatment Facilities at that time, concerns about the original choice of the phosphate-based treatment strategy remained strong within the Agency through 1996. These concerns were further amplified by a change in the procurement of the treatment chemical, in May 1995, from a sole-source supplier of a "proprietary" 36% blended orthophosphate (Shannon SLI-1226, previously called a "calcium orthophosphate") to chemically equivalent 36% orthophosphoric acids (termed "generic"), obtained via open market competition.

In August 1996, in response to the general failure of the treatment program to produce regular compliance with the EPA 90th percentile lead action level, and continued concerns about the choice of treatment approach, a proposal for an additional water treatment pilot study was put forward. This pilot study has become regarded as the Phase II Corrosion Control Study to distinguish it from the original aforementioned study conducted during 1991 and 1992.

OBJECTIVES OF THE PHASE II CORROSION CONTROL PILOT STUDY

In 1996, based upon a series of discussions with administrative and technical staff within the Division of Drinking Water Quality Control (DWQC), the Phase II Study was developed for the purpose of addressing the following issues:

Issue 1:
Is there a difference between the performance of a proprietary blended 36% liquid orthophosphate product (for example, Shannon SLI-1226) in reducing plumbosolvency vs. a generic 36% liquid orthophosphoric acid product?

Hypothesis related to Issue 1:
There is no difference, since both products have the required 36% orthophosphate content, which forms the necessary reactive phosphate (PO_4^{3-}), upon dissociation, involved in the kinetics of passivation film formation on the surfaces of lead appurtenances.

Issue 2:
Assuming that the Hypothesis to Issue 1 is true, is the 2.5 ppm "as product" dosage, which provides a 0.9 ppm residual phosphate concentration in the distribution system, the correct long-term maintenance dosage regardless of the supplier of the product?

Hypothesis related to Issue 2:
It is likely that a higher orthophosphate dosage than the 2.5 ppm "as product" dosage, originally recommended by the 1991-1993 Corrosion Control Study, should be applied to drinking water entering the City's distribution system at Hill View Reservoir. The resulting 0.9 ppm residual phosphate concentration may not be optimal for actual distribution system water quality conditions.

A review of keypoint data from DWQC Central Laboratory will reveal an increase in the free residual chlorine level being maintained at the entry points to the City's distribution system (Bx4 and Bx5) from January 1992 to February 1996. This increase is attributable to the promulgation of the Total Coliform Rule in 1991. In addition, since New York City maintains an unfiltered water supply system, chlorination remains the primary mode of treatment optimization in response to adverse water quality events such as high turbidity or bacteria counts.

An unintended result of adding higher dosages of chlorine to the distribution system may be the reduced effectiveness of the orthophosphate corrosion inhibitor. The 1991-1993 Corrosion Control Study was conducted using a simulated distribution system maintained with an Entry Point chlorine residual reflective of pre-1991 values of +/- 0.7 ppm.

Issue 3:
Should the City be employing a different type of phosphate-based treatment chemical (e.g. zinc orthophosphate, zinc meta-phosphate, sodium polyphosphate, blended poly/orthophosphate) than the kind presently being applied?

Proposed Hypothesis to Issue 3:
The blended orthophosphate treatment chemical currently being added to the City's drinking water was chosen based upon the results and findings of the 1991-1993 Corrosion Control Study.

As stated above, the molecular species which most controls the passivation of lead surfaces, after accounting for dissolved inorganic carbonate (DIC), is the "reactive" phosphate (PO_4^{3-}) available in orthophosphate products. A review of the scientific literature, available from regulatory, academic, non-profit and industry sources, reveals that the presence of a formula cation such as divalent zinc, Zn^{2+}, is not considered significant to passivation film formation.

Polyphosphates are inorganic polymeric chains made from individual orthophosphate units. Polyphosphates have traditionally been used as sequestering agents by water supplies experiencing high levels of suspended iron and manganese. Polyphosphates are also known to dissolve iron tubercles and passivate iron-based surfaces exposed in distribution mains. Successful passivation of a lead surface using polyphosphate treatment occurs only after the polyphosphate molecules revert, *in-situ*, to the orthophosphate state.

Thus, all products of equal value in terms of *percentage orthophosphate* concentration, should perform equally.

PROCEDURE FOR THE PHASE II CORROSION CONTROL PILOT STUDY

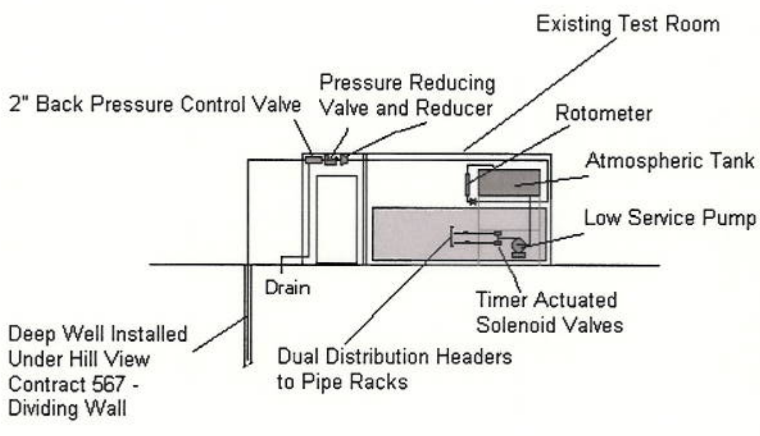
Using the previously stated issues (and hypotheses) as a basis, a pilot study proposed by the Division's Water Treatment Planning and Analysis Unit (WTPAU) in August 1996, and presented to Division Management for review and approval. Capitalizing on experience gained from the 1991 to 1992 study, a four (4) pipe rack pilot treatment system was proposed for the former Corrosion Control Study experimental station in Uptake Chamber No. 2 at Hill View Reservoir. The experimental station is housed inside a wood framed 16 foot by 24 foot lighted and heated room, which also contains a DWQC water quality compliance monitoring station (Bx2) on the southern wall. At this location it is possible to obtain water directly from the Delaware Aqueduct prior to caustic, chlorine and orthophosphate treatment at Hill View Reservoir. However, the means of supplying adequate water for the new pilot study required an additional deep well pump installation which occurred during the Winter of 1997-1998 under the auspices of Hill View Contract 567.

Construction of the pilot facilities began with fabrication of the pipe rack assemblies at the Demonstration Water Treatment Plant during the summer of 1997 by WTPAU staff. Renovation of the experimental station and installation of the pipe racks at Uptake Chamber No. 2 began during the fall of 1997. The remaining physical and electronic systems of pilot plant were completed in March 1998 with assistance from DEP Construction Services.

Description of Pilot Plant Facilities

Water taken directly from Shaft 1A North is pumped through a 2 in. Sch. 80 PVC riser, regulated to a rate of 15 gallons per minute (gpm), and delivered to an elevated atmospheric tank situated inside the room (see Figure 1). There, a centralized treatment of caustic soda (sodium hydroxide, 50 w/o) and liquid chlorine (15% sodium hypochlorite solution) can be applied. Effluent from the tank flows by gravity to a low service booster pump (1/3 hp) then divided between two 0.5 in. Sch. 80 PVC headers, each of which serves two pipe rack assemblies at a rate of 3 gpm each. In order to simulate the diurnal on/off cycle of a residential plumbing system, flow from the tank will be controlled by a timer-actuated solenoid valve situated on each 0.5-inch header, which operates simultaneously with the low service pump. (During non-distribution periods, treated water overflows from the tank via two drains and directed to a sanitary sewer.)

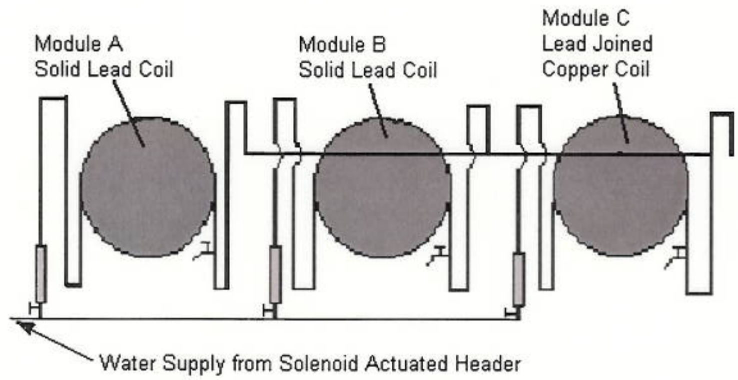
Figure 1 - Water Supply System for Pipe Racks



A schematic of a typical pipe rack is shown in Figure 2. It is comprised of two 1 in. OD by 20 foot length lead coils and one 0.5 in. OD by 25 foot length Type L copper coil with 9 lead soldered joints, each of which receives a 1 gpm flow (3 gpm total) via a common delivery manifold system constructed of 0.75 in. Sch. 80 PVC. During the programmed periods of non-flow the hydraulic arrangement arrests water in the coils, simulating a "standing water" condition.

Each pipe rig header has provision for receiving a corrosion inhibitor with adequate mixing prior to the first coil. Sample taps are provided at the outlet of each of the coils for water quality analysis. In addition, there are three "flow-thru tee" locations to allow for the insertion of probes to continuously monitor pH, temperature, free chlorine residual and oxidation-reduction potential (ORP).

Figure 2 - Schematic of Pipe Rack System
(not to scale)



As recommend by the American Water Works Association Research Foundation (AWWARF)[1], the timing cycle for flow to the pipe rigs will be set as follows:

Time	Cycle Mode
6:00 am	on
7:00 am	off
12:00 pm	on
12:30 pm	off
5:00 pm	on
6:00 pm	off
10:30 pm	on
11:00 pm	off
1:30 am	on
2:00 am	off

A centralized treatment of sodium hydroxide and sodium hypochlorite in the atmospheric tank obviates the need for individual chlorine and caustic metering systems, and insures the same baseline water quality conditions for all of the four pipe racks. Baseline treatment is controlled so that pH and free residual chlorine conditions replicate those being maintained in the City's distribution system.

To date, the four pipe rig assemblies have been subject to the following corrosion control treatment strategies:

Rack No. 1:
Passivation at 2.0 ppm applied phosphate dose, then maintenance at 1.0 ppm applied phosphate dose, employing present generic product being supplied by Carus Chemical Company.

Rack No. 2:

Passivation at 2.0 ppm applied phosphate dose, then maintenance at 1.0 ppm applied phosphate dose, employing "proprietary" orthophosphate formulation SLI-1226 manufactured by the Shannon Chemical Company.

Rack No. 3:

Passivation at 2.0 ppm applied phosphate dose, then maintenance at 1.0 ppm applied phosphate dose, employing 3:1 ratio zinc orthophosphate supplied by the KJELL Corporation.

Rack No. 4:
As requested by DWQC Management, blended poly/orthophosphate treatment using a product known as "Seaquest" manufactured by Aquasmart, Inc at a 2.2 ppm as product applied dose.

Continuous water quality monitoring systems were installed to measure pH, temperature, free residual chlorine, and oxidation-reduction potential of the incoming aqueduct water and treated water at various points in the experimental system. Utilizing analog telemetry, 4-20 ma data signals from the water quality monitors are processed by an Omega ® data acquisition system and recorded onto a Compaq Armada™ laptop personal computer, which serves as a data logging device.

Start-Up

Shake down of the pilot plant transpired from April to May 1998. During this time period hydraulic tests were conducted, leaks in the pipe rack system were discovered and repaired, faulty water quality monitors were replaced and the computer's hard drive was repaired.

In June 1998, prior to placement into service, a solution of sodium bisulfite reducing agent (trade name *Iron Ike*) was individually metered into each pipe rack assembly while each was being flushed with Delaware Aqueduct water continuously for a 24-hour period. Following this procedure, the pipe rack systems were flushed continuously for a 1-week period using only Delaware Aqueduct water.

Prior to applying the various corrosion inhibitor treatments to the pipe racks, two different baseline assessments were conducted; the results of which will be discussed later in this report:

Normal Operating Procedure

With proper planning and additional staffing, maintenance of the pilot plant operation was often reduced to one day per week. On a predetermined weekly sampling day (normally on Wednesday), a WTPAU staff member performs the following tasks:

- assess the chemical charges and replenish as necessary,
- download stored electronic data from the laptop computer onto a 3.4" floppy disk,
- collect samples,
- restart pipe racks and insure that baseline treatment of sodium hypochlorite and sodium hydroxide is providing a level of

1ppm free residual chlorine and a pH between 7.0 and 7.5 to all four pipe racks.
- determine orthophosphate levels in each pipe rack using portable DR-100 Phosphate Spectrophotometer,
- adjust corrosion inhibitor chemical metering pumps accordingly,
- record observations and efforts in log book.

Sample Collecting Procedure

The corrosion study pilot is comprised of twelve (12) coils, mounted in four sets (or racks) of three (4x3), which are designated by the following identification system:

Rack 1: Pb1A, Pb1B, Cu1;
Rack 2: Pb2A, Pb2B, Cu2;
Rack 3: Pb3A, Pb3B, Cu3;
Rack 4: Pb4A, Pb4B, Cu4.

Each coil has a sample tap. Once the experimental program is underway, "first draw" samples are to be collected every Wednesday morning at 11am according to the following procedure.

1) Obtain twelve 250 ml acid washed Nalgene containers for metals analysis, and twelve 100 ml plastic graduated cylinders from DWQC Kensico Laboratory.
2) Label the twelve containers and cylinders according to the following sequence: Pb1A, Pb1B, Cu1, Pb2A, Pb2B, Cu2, Pb3A, Pb3B, Cu3, Pb4A, Pb4B, Cu4; this is in order to correspond to the individual coil sampling taps. Also, mark the date of sample collection on the label of every Nalgene container. Each tap should now have its own dedicated 250 ml Nalgene container, and 100 ml plastic graduated cylinder associated with it.
3) When sampling, go in sequence according to the labeling system. First use the designated graduated cylinder to draw and waste a 100 ml aliquot of effluent from the tap.
4) Then take another 100 ml aliquot into the graduated cylinder and transfer it to the appropriately labeled 250 ml Nalgene container, replacing the cap immediately.
5) Repeat steps 4 and 5 until all twelve coils are sampled.
6) Following the appropriate chain of custody procedures, return all samples to Kensico Laboratory for ICP Total Metals scan or AA analysis for Total Lead. Submit graduated cylinders for washing and subsequent reuse.

RESULTS AND DISCUSSION

Baseline Study

During the period from June 1998 through March 1999, the pipe rack systems were subject to an alternating protocol consisting of first receiving Delaware Aqueduct water (via Sh. 1A North) for a two week interim, followed by receiving Delaware Aqueduct water treated with sodium hydroxide, for a target pH of 7.5, for a two week interim. Samples were collected on a weekly basis according to the procedure outlined in the previous section.

The reason for this approach results from the 1991-1992 study, during which it was observed that the adjustment of Delaware Aqueduct water to a pH of 7.5, without any further treatment, had a significant effect on reducing plumbosolvency in coils of solid lead (Figure 3). Whereas the opposite effect was observed on copper coils joined with 50% lead content solder (Figure 4).

Figure 3
Phase I Corrosion Control Study
Solid Lead Loops

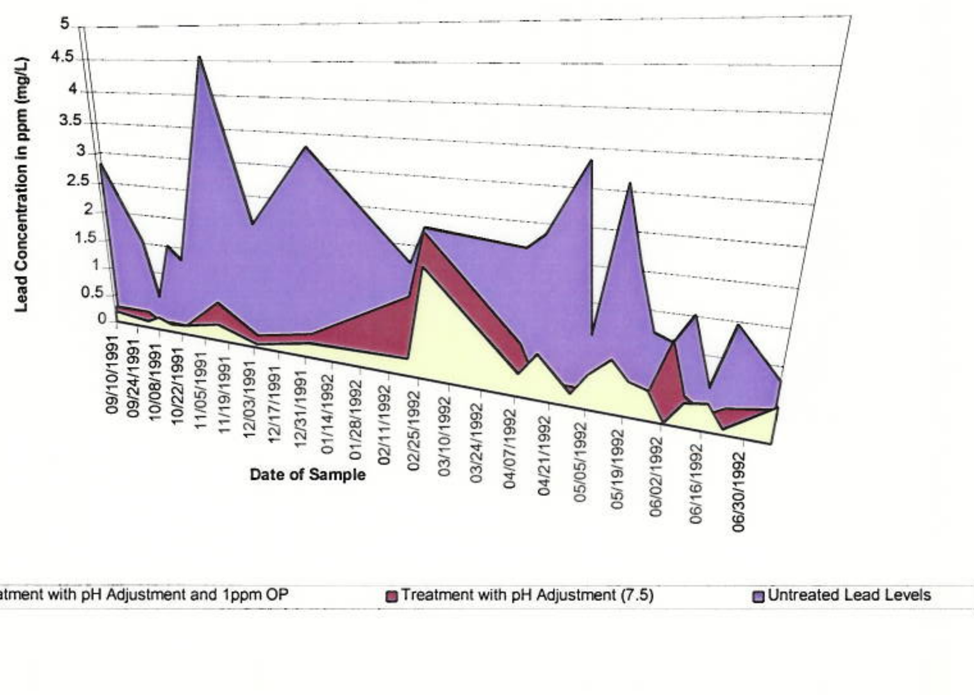
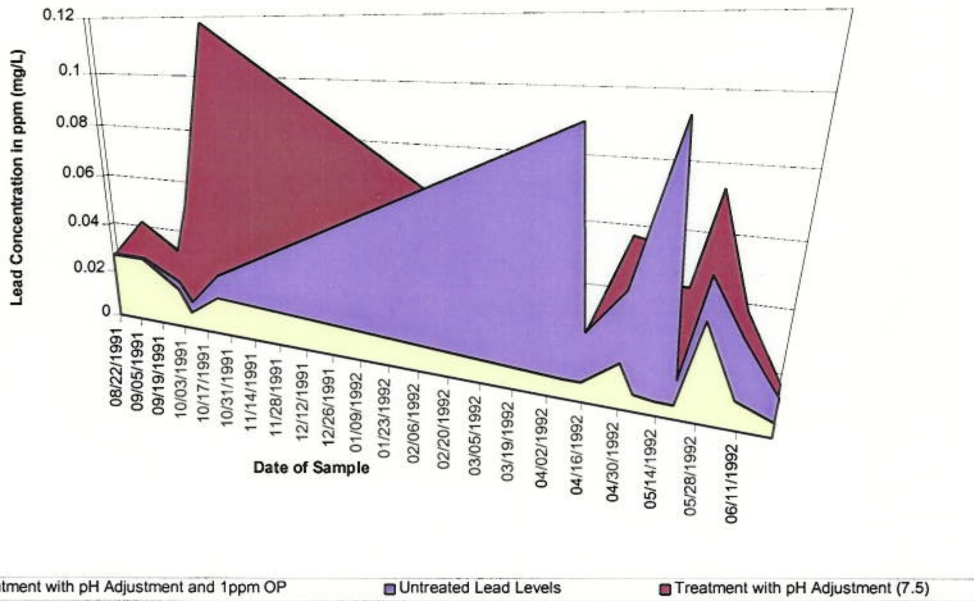


Figure 4
Phase I Corrosion Control Study
Lead Soldered Copper Coils



Solid Lead Coils
Since all four pipe racks were simultaneously exposed to the same protocol during the Baseline study, it was possible to employ a sample from each loop during the Baseline Study period, thereby enhancing the statistical database for future analysis. A total of 56 samples were collected during the "no treatment" intervals, and 64 were collected during the "pH adjustment" intervals. Sample results for the solid lead coils is presented below, all values are in parts per billion ($\mu g/L$):

TABLE 1 (Solid Lead):

Delaware Aqueduct Water								
Date	**Pb1A**	**Pb1B**	**Pb2A**	**Pb2B**	**Pb3A**	**Pb3B**	**Pb4A**	**Pb4B**
07/07/1998	111	112	218	270	145	64	137	191
07/09/1998	88	81	78	297	80	71	1580	226
10/15/1998	103	97	413	176	310	47	83	86
10/20/1998	225	374	123	150	99	91	138	74
10/23/1998	86	316	150	131	170	57	77	65
11/05/1998	123	58	149	610	50	46	163	75
11/06/1998	144	60	121	181	102	52	124	5780

TABLE 2 (Solid Lead):

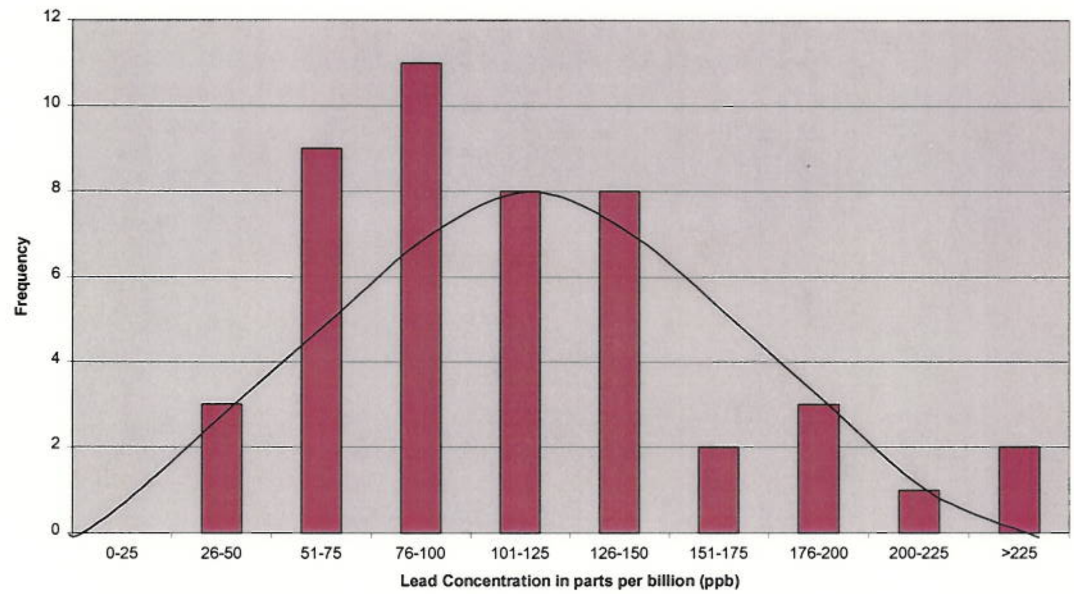
Delaware Aqueduct Water (With NaOH addition for pH 7.5)								
Date	**Pb1A**	**Pb1B**	**Pb2A**	**Pb2B**	**Pb3A**	**Pb3B**	**Pb4A**	**Pb4B**
06/17/1998	20	18	22	124	58	15	110	45
06/18/1998	18	15	21	59	19	10	76	12
08/20/1998	43	113	836	821	22	29	123	64
09/17/1998	69	91	114	383	146	196	131	37
09/24/1998	38	40	189	36	178	25	131	239
02/18/1999	57	18	41	74	84	37	n.a.	n.a.
03/04/1999	24	29	106	30	14	11	83	180
03/09/1999	28	18	n.a.	66	22	72	28	45

(n.a. = not analyzed)

Delaware Aqueduct Water (No Additional Treatment)

Inspection of this data set reveals several values immediately considered to be outliers: 5780, 1580, 610, and 413 $\mu g/L$. Additional values were eliminated from the data set through 95% confidence interval testing resulting in the following distribution of data:

Figure 5
Histograph of Lead Results at Shaft 1A North:
No Additional Treatment



In the histograph shown in Figure 5, the bars represent the actual distribution of the data with outliers removed, the line represents a normal probability distribution calculated from the sample population, mean and standard deviation.

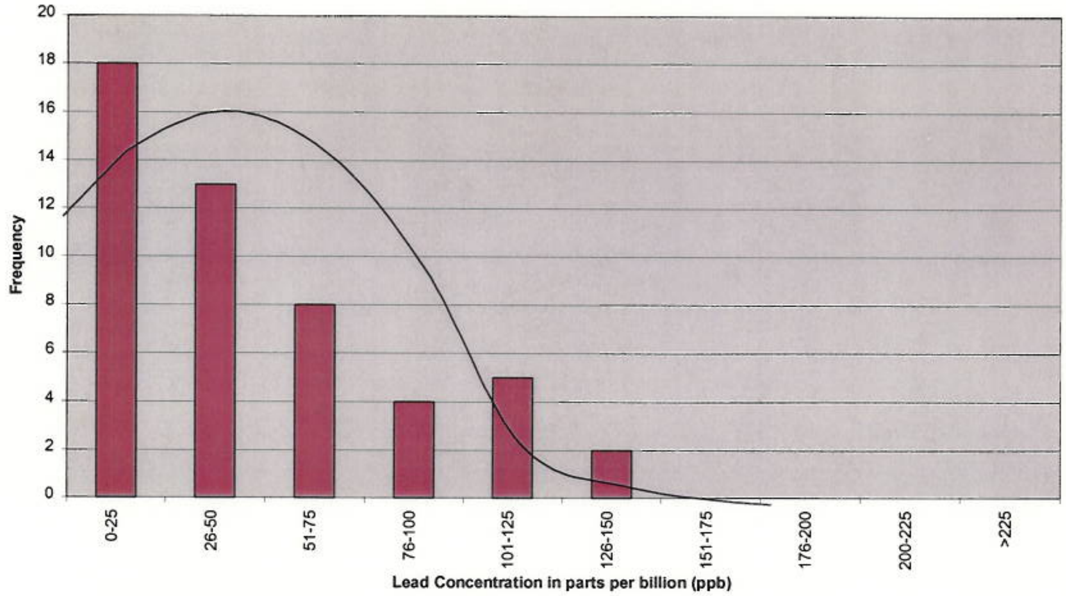
$y = 1/\sqrt{2\pi\sigma e\text{-}[(\text{Value-}\eta)^2/2\sigma^2]}$

σ (standard deviation) = 55 $\mu g/L$
η (mean) = 115 $\mu g/L$
n (sample population) = 47

Delaware Aqueduct Water (With NaOH addition for pH 7.5)

As with the previous data set, inspection revealed several values immediately considered to be outliers: 821and 836 μg/L . Additional values were eliminated from the data set through 95% confidence interval testing resulting in the following distribution of data:

Figure 6
Histograph of Lead Results at Shaft 1A North:
pH 7.5 and 1 ppm Free Residual Chlorine



In the histograph shown in Figure 6, the bars represent the actual distribution of the data with outliers removed, the line represents a normal probability distribution calculated from the sample population, mean and standard deviation.

$y = 1/\sqrt{2\pi\sigma e\text{-}[(\text{Value-}\eta)^2/2\sigma^2]}$

σ (standard deviation) = 50 μg/L
η (mean) = 36 μg/L
n (sample population) = 50

Analysis:

Scientific literature describing the statistical behavior of data resulting from corrosion loop studies[2] supports the skewed (non-normal) distribution pattern shown on the previous bar graphs. To compare differences in treatment effectiveness AWWARF[3] recommends a non-parametric procedure, the Wilcoxon Signed Rank Test, to test the Null Hypothesis.
In so doing, what was visually obvious by comparison of the distributions shown on Figures 5 and 6 was indeed confirmed by this document's authors: *on solid lead appurtenances, the influence of a pH increase alone resulted in significant reduction of plumbosolvency.* This phenomenon is likely due to a shift in chemical equilibrium favoring the production of more stable, less soluble, hydrocerrusite $(Pb_3(CO_3)_2(OH)_2$ over cerrusite $(PbCO_3)$ at the pipe surface[4].

Lead-Joined Copper Coils
Due to a delay in the fabrication of the 25' copper coils joined with high lead content solder, the investigation of the effectiveness of pH increase alone was based on a data set over 50% smaller than that of the solid lead coils. Sample results for the lead-joined copper coils is presented below, all values are in parts per billion (μg/L):

TABLE 3 (Lead -Joined Copper):

Delaware Aqueduct Water				
Date	**Cu1**	**Cu2**	**Cu3**	**Cu4**
10/15/1998	12	8	10	30
10/20/1998	49	9	12	8
10/23/1998	43	6	14	5
11/05/1998	9	5	5	9
11/06/1998	5	3	9	6
01/11/1999	18	2	45	37
06/29/1999	4	14	12	24
07/01/1999	5	6	5	10

TABLE 4 (Lead -Joined Copper):

Delaware Aqueduct Water (WithNaOH addition for pH 7.5)				
Date	**Cu1**	**Cu2**	**Cu3**	**Cu4**
09/17/1998	26	93	497	207
09/24/1998	12	7	57	29
02/18/1999	29	251	498	n.a.
03/04/1999	91	176	118	50
03/09/1999	14	n.a.	107	92
07/08/1999	15	39	47	81
07/12/1999	4	39	3	35

(n.a. = not analyzed)

Delaware Aqueduct Water (No Additional Treatment)

Unlike the treatment of the data obtained from the solid lead coils, there was no removal of outliers by testing or inspection due to the significantly smaller data set. Figure 7 shows the distribution of the sample results for the lead-joined copper coils subject to the "no additional treatment" baseline condition.

Delaware Aqueduct Water (With NaOH addition for pH 7.5)

Figure 8 shows the distribution of the sample results for the lead-joined copper coils subject to the "pH increase" baseline condition.

Analysis

In the absence of subjecting the data to statistical analysis, there is evidence of a strong change in the behavior of the sample population, suggesting an increase in plumbosolvency when the lead-joined coils receive Delaware Aqueduct treated with sodium hydroxide. That such an increase in plumbosolvency is actually occurring is supported not only by the observations made during the 1991-1992 Corrosion Control Study, but by the scientific literature[1] as well. Simply stated, the joining of dissimilar metals creates a galvanic cell favoring the release of the less noble metal, in this case the 50% lead content solder. An increase in hydroxide species availability will exacerbate this phenomenon in low alkalinity surface water supplies.

Figure 7
Histograph of Lead Results at Shaft 1A North:
No Additional Treatment
Lead-Joined Copper Coils

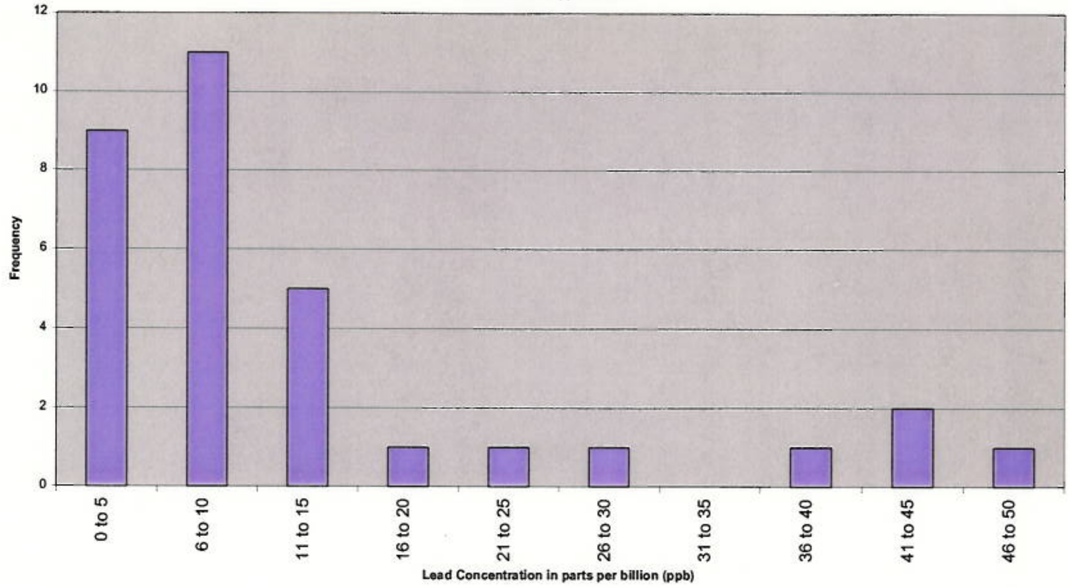
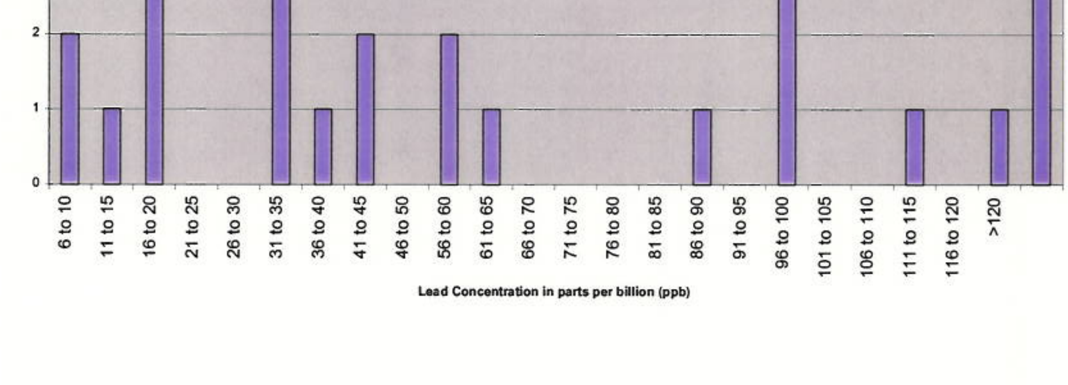


Figure 8
Histograph of Lead Results at Shaft 1A North:
pH 7.5 and 1 ppm Free Residual Chlorine
Lead-Joined Copper Coils



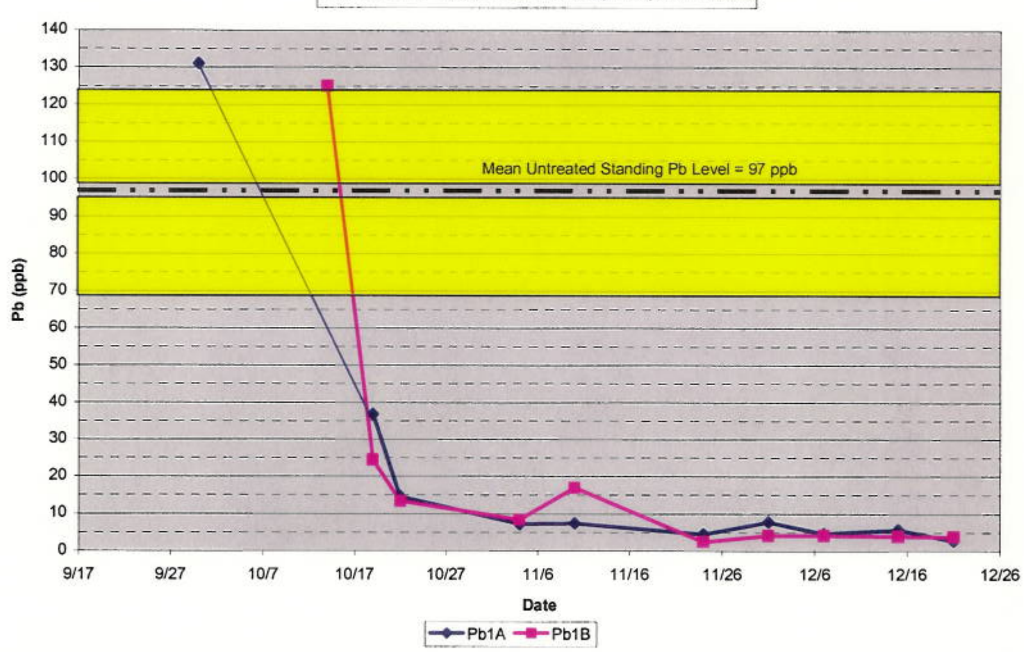
Effect of Phosphate Corrosion Inhibitors

It has been demonstrated that the hydroxide ion (OH^-) has a strong influence in controlling lead solubility from various types of appurtenances. The formation of relatively insoluble films on the surfaces of lead-bearing materials can be further influenced by the presence of reactive phosphate. Lead forms several phosphate complexes known to be even less soluble than those formed with hydroxides or carbonates over a wide pH range. Under potable water conditions, the most likely phases to form are hydroxypyromorphite ($Pb_5(PO_4)_3OH$) or teriarty lead phosphate ($Pb_3(PO_4)_2$). Refer to the *Final Report on the Corrosion Control Study for the New York City Water Supply System (March, 1993)* for an illustrated discussion of this topic.

Solid Lead Coils

From September 30 to December 21, 1999, the four pipe rack systems were treated with phosphate-based corrosion inhibitors according to the plan described in the Procedure section of this report. The results of this effort are shown graphically in Figures 9 through 12. The plots indicate the mean untreated standing lead for the combined results of the two solid lead coils of a given rack, with a 95% confidence interval represented by the yellow shaded area, overlaid by the first draw sample results during the 3-month treatment period.

Figure 9 - Corrosion Control Study
First Draw Sample Results for Solid Lead Coils
Pipe Rack 1 - Carus 36% Orthophosphoric Acid



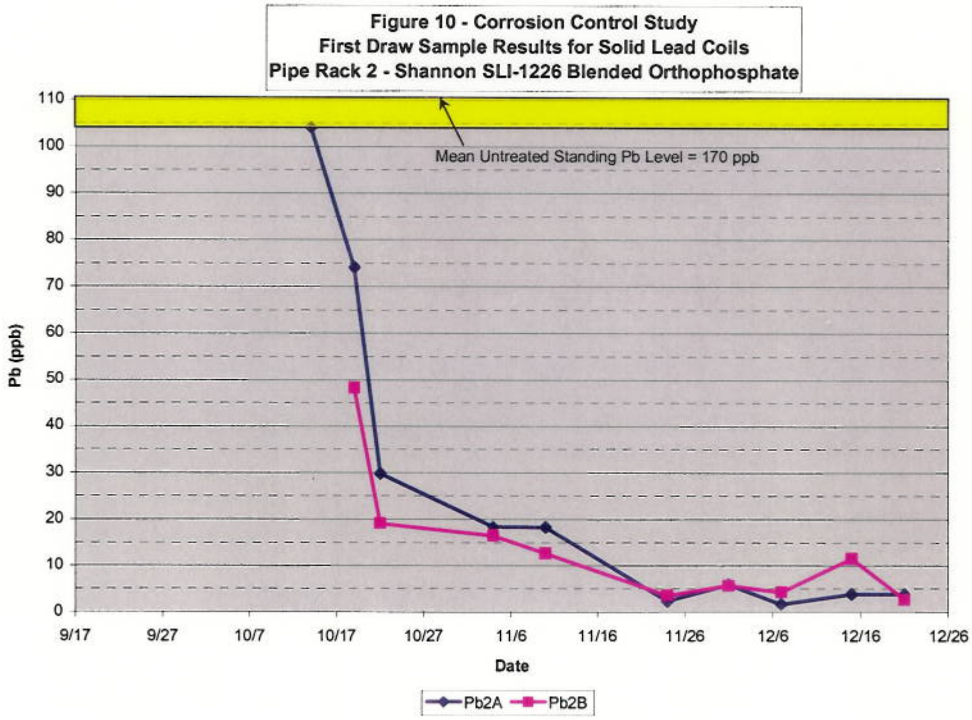


Figure 10 - Corrosion Control Study
First Draw Sample Results for Solid Lead Coils
Pipe Rack 2 - Shannon SLI-1226 Blended Orthophosphate
Mean Untreated Standing Pb Level = 170 ppb
Pb (ppb)
Date
Pb2A
Pb2B

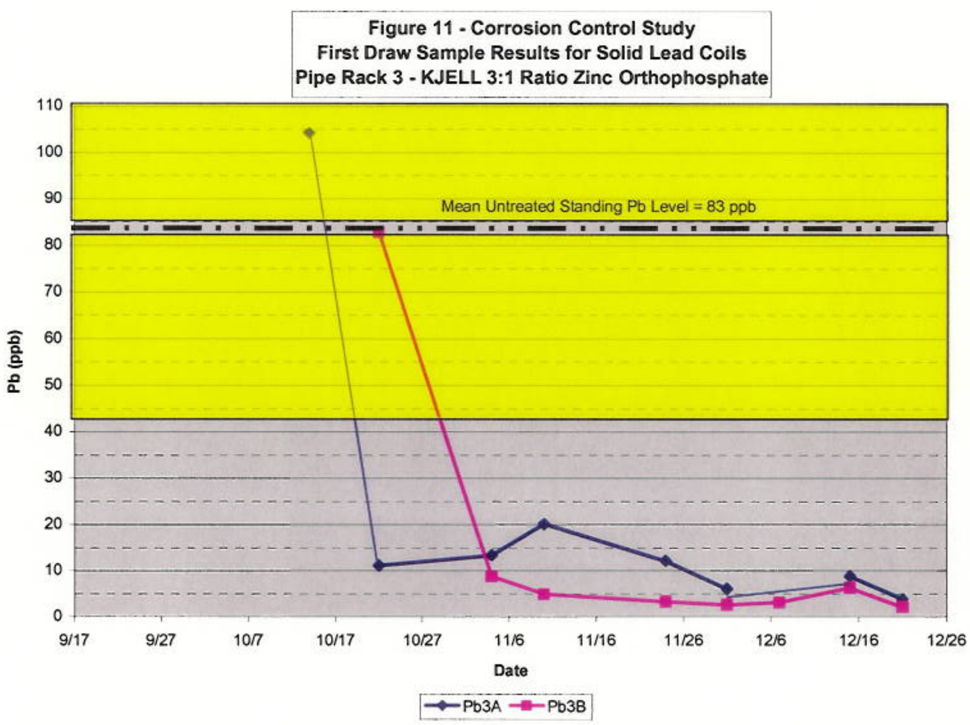
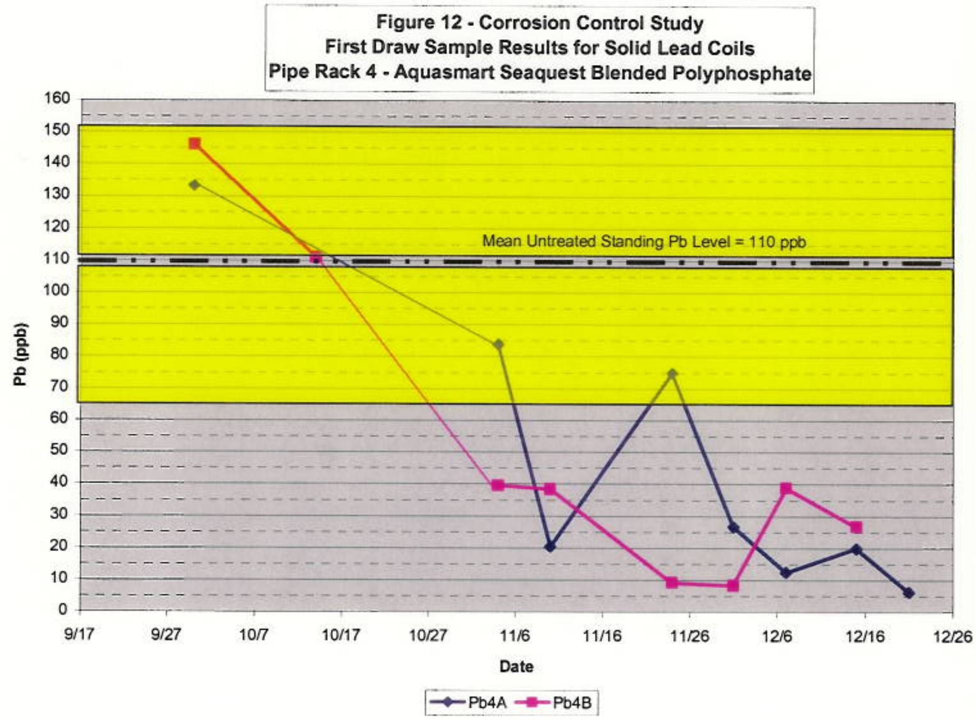


Figure 11 - Corrosion Control Study
First Draw Sample Results for Solid Lead Coils
Pipe Rack 3 - KJELL 3:1 Ratio Zinc Orthophosphate
Mean Untreated Standing Pb Level = 83 ppb
Pb (ppb)
Date
Pb3A
Pb3B



Aside from the graphical representations shown above, there has been no further statistical analysis of the data from this period of pilot testing. During a presentation to DWQC scientific staff on March 16, 2000, it was determined by consensus that these results support the following assertions:

1. There is no difference between the performance of orthophosphate products meeting our current product specifications, whether they are "generic" or "proprietary".

2. A zinc-bearing phosphate corrosion inhibitor does not appear to out-perform a non zinc-bearing inhibitor.

3. The use of a blended polyphosphate treatment chemical, normally used as a sequestering agent for iron and manganese, as a corrosion inhibitor remains questionable and will likely not be advocated for further study.

Lead-Joined Copper Coils

The results of phosphate corrosion inhibitor testing on lead-joined copper coils are depicted in Figures 13 through 16. Unlike results for the Solid Lead Coils, that a consistent reduction in lead solubility is occurring appears considerably less evident. Linear regression trend lines support a decrease in standing water lead levels over time, but with considerable scattering of the data as evidenced by the values of the correlation coefficient, R^2. However, it should be noted that most statistically significant results coincided with Pipe Rack 1, employing the Carus 36% Orthophosphoric Acid (considered a "generic" product) presently in use at Hill View Reservoir.

At the recommendation of the DWQC scientific staff, continued pilot studies are to incorporate additional testing of lead-joined copper coils subject to orthophosphate treatment.

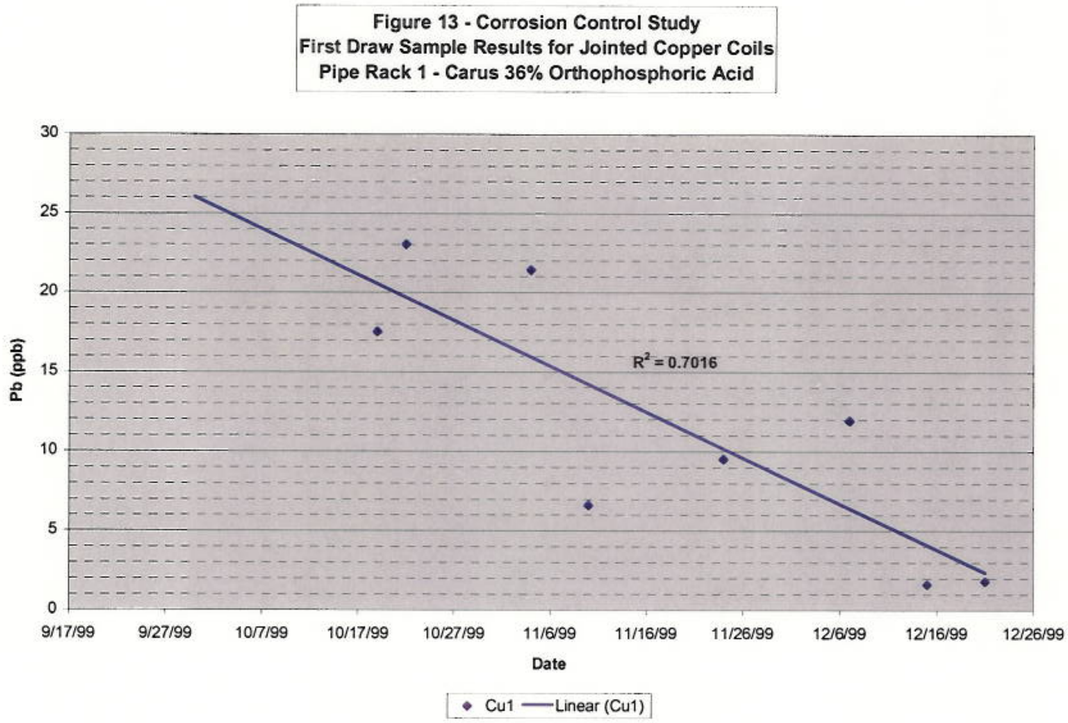


Figure 13 - Corrosion Control Study
First Draw Sample Results for Jointed Copper Coils
Pipe Rack 1 - Carus 36% Orthophosphoric Acid
Pb (ppb)
30
25
20
15
10
5
0
$R^2 = 0.7016$
9/17/99
9/27/99
10/7/99
10/17/99
10/27/99
11/6/99
11/16/99
11/26/99
12/6/99
12/16/99
12/26/99
Date
Cu1
Linear (Cu1)

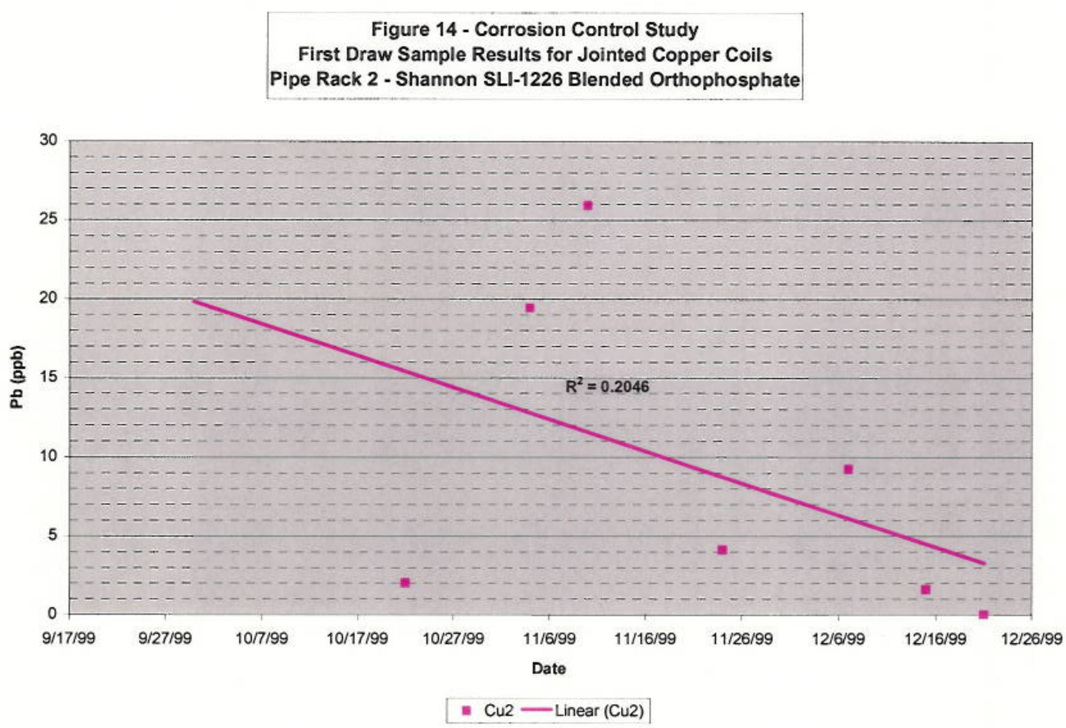


Figure 14 - Corrosion Control Study
First Draw Sample Results for Jointed Copper Coils
Pipe Rack 2 - Shannon SLI-1226 Blended Orthophosphate
Pb (ppb)
30
25
20
15
10
5
0
$R^2 = 0.2046$
9/17/99
9/27/99
10/7/99
10/17/99
10/27/99
11/6/99
11/16/99
11/26/99
12/6/99
12/16/99
12/26/99
Date
Cu2
Linear (Cu2)

Figure 15 - Corrosion Control Study
First Draw Sample Results for Jointed Copper Coils
Pipe Rack 3 - KJELL 3:1 Ratio Zinc Orthophosphate

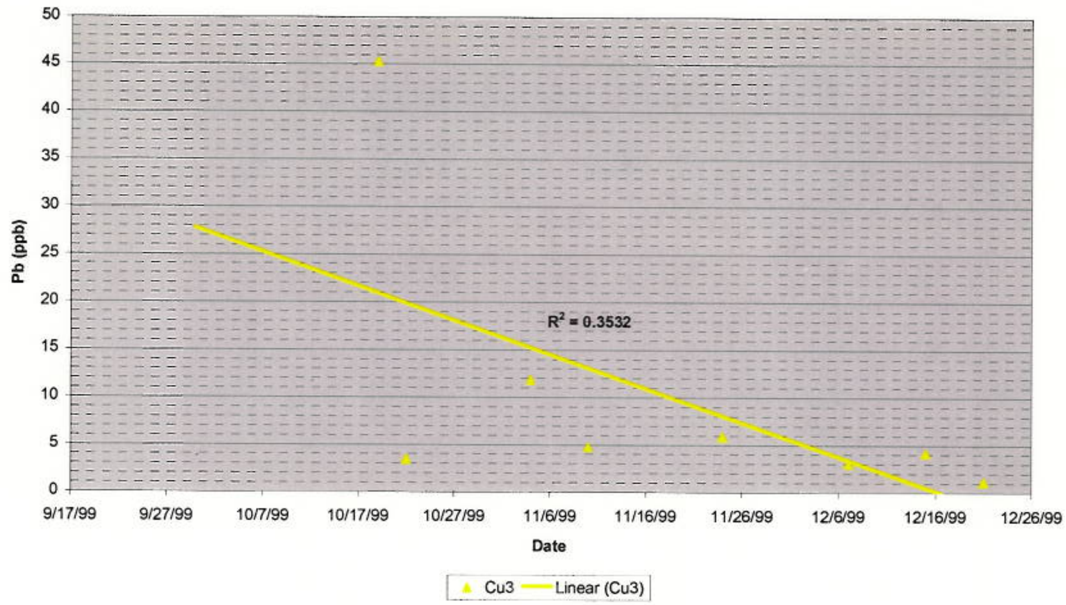
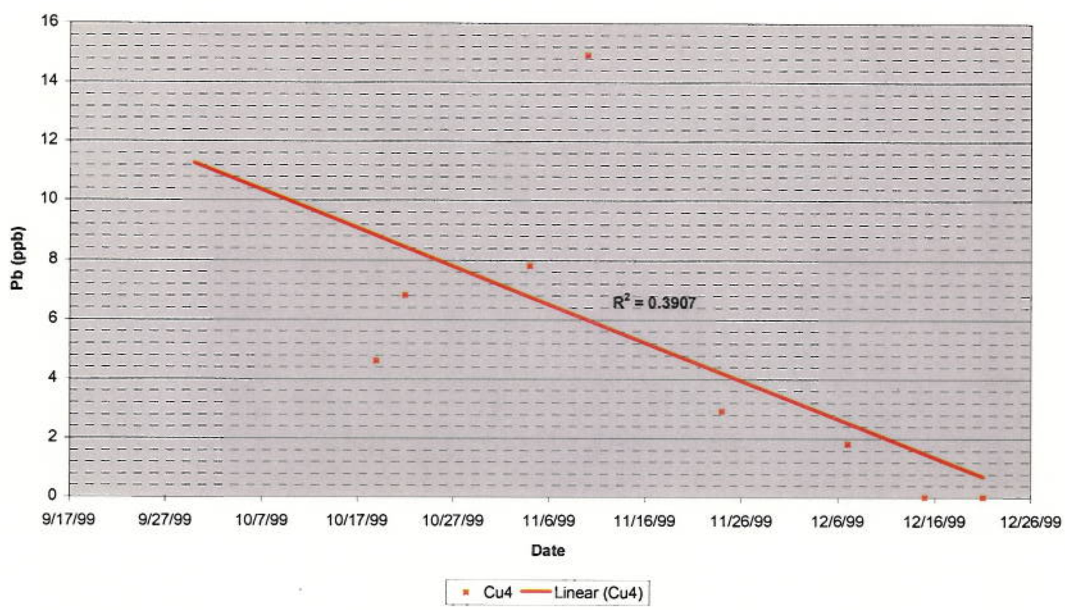


Figure 16 - Corrosion Control Study
First Draw Sample Results for Jointed Copper Coils
Pipe Rack 4 - Aquasmart Seaquest Blended Polyphosphate



CONCLUSIONS

The Phase II Corrosion Control Study, thus far, has been instrumental in supporting the conclusions of the 1991-1992

Corrosion Control Study as it pertains to the choice of corrosion treatment selected for New York City's drinking water. This has been further supported by the results of the past two consecutive regulatory monitoring periods, where compliance with the Lead and Copper rule's 90th percentile lead action level of 15 ppb was attained. Additionally, improvements in protocols applied to Treatment Operations, along with advances in daily monitoring of distribution system conditions, particularly pH levels, have played a significant role in improving the performance of the orthophosphate corrosion inhibitor since 1996.

During presentation of the foregoing material to the DWQC scientific staff, consensus was reached on a number of key issues:

1. There is no difference between the performance of orthophosphate products meeting our current product specifications, whether they are "generic" or "proprietary". The product currently in use, Carus 36% Orthophosphoric Acid, considered a "generic", has been effective as a corrosion inhibitor for residential lead plumbing surfaces.

2. A zinc-bearing phosphate corrosion inhibitor does not appear to out-perform a non zinc-bearing inhibitor. While additional pilot testing may provide a more definitive answer, there does not appear to be much impetus for further testing of this type of product.

3. The use of a blended polyphosphate treatment chemical, normally used as a sequestering agent for iron and manganese, as a corrosion inhibitor remains questionable and will likely not be advocated for further study.

4. The pH factor plays a significant role in controlling lead solubility from plumbing surfaces. However, since maintaining New York City distribution system pH levels above 7.0 leads to significant increases in disinfection by-product formation, we should seek to establish effective corrosion control at the lowest practical pH level possible.

5. Future pilot testing can employ the current "generic" orthophosphate corrosion inhibitor exclusively, with the focus on the lowest treated water pH practical for effective corrosion treatment and downstream disinfection.

6. Future pilot testing should also focus on obtaining more data on the response of lead-joined copper surfaces to orthophosphate treatment.